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# Microwave dielectric study of Pearl Millet *(Pennisetum typhoides)* at 9.85 GHz frequency

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**Abstract**

Values of dielectric constant ($\in'$), dielectric loss ($\in''$), relaxation time ($\tau_p$), conductivity ($\sigma_p$) and moisture content of pulverized Pearl millet were measured for different packing densities at 9.85 GHz microwave frequency and at different temperature ( 20˚C, 35˚C and 50˚C). Experimental results on powders of different packing fractions ($\delta_r$) were used to obtain transformation to 100% solid bulk using correlation formulae of Landau-Lifshitz-Looyenga and Bottcher. Moisture content was measured by Thermo- gravimetric method. It is found that, there was fair agreement between the calculated values of dielectric parameters and the values obtained experimentally for solid bulk. This shows cohesion in the particles of Cinnamon bark powders under investigation.

**Keywords:** Pearl Millet, Dielectric constant, Loss, Conductivity, Moisture.

## INTRODUCTION

This is the second important millet of India. The area under the crop is 28.2 million acres, and the annual production of grain is about three million tons. It is chiefly cultivated in U. P., Punjab, A.P., and Maharashtra.

In India the crop is grown mainly in Kharif season. The plants are tall annuals, growing to a height of from 6 feet to 15 feet. The inflorescence is a dense spike like head or panicle 6 to 15 inches long and 1 inch or so in diameter. In India it is grown as a rainy season crop.

It furnishes an important food for the poor people and labour class and is particularly valuable in cold weather because of its heating qualities. The flour made from the grain is very nutritious and is used for making bread. The crop has an enormous yield of forage.

To obtain useful information on biophysical properties of various kinds of agricultural products, the study of dielectric behavior from microwave absorption is of great value. The dielectric properties of agricultural products describe interaction [1, 5, 6, 8 and 9] with microwave energy and depend on the frequency of electromagnetic field as well as on bulk particle properties of the materials such as moisture content, density, temperature packing fraction and composition. The dielectric heating effect on germination, early growth of agric-products, improvement in nutritional quality, stored-grain insect control, drying of grains, sterilization of grains etc, is of great importance to know the actual process at molecular level. To get some information in this direction, dielectric properties of Pearl Millet were determined at various packing fractions and temperatures.

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## MATERIALS AND METHODS

For the determination of dielectric parameters of Pearl Millet, three samples of various particle sizes were prepared by using sieves of different sizes and transferred into the glass bottles and sealed immediately to avoid moisture intake. They were opened while taking readings. Thermo-gravimetric method is used for moisture content. To determine the relative packing factor ($\delta_r$) density for each powder samples were measured. Measurement of dielectric constant ($\in'_p$) and loss factor ($\in''_p$) for these powder samples of different packing fractions was made using reflectometric technique at 9.85 GHz of X- band [10 and11] microwave frequency and at different temperatures (20˚, 35˚ and 50˚C).

For better results, accurate measurement of dielectric wavelength ($\lambda_d$) is necessary. This was done by introducing the powder slowly in the sample holding dielectric cell in steps and applying constant 98 N-force on the sample. The corresponding reflection co-efficient is measured by using crystal pick in the directional coupler. The relationship between reflected power and the sample column position is approximately given by damped sinusoidal curve. The distance between two adjacent minima gives half the dielectric wavelength ($\lambda_d$). For the accurate measurements of the dielectric wavelength ($\lambda_d$) Kalamse [13] have designed and fabricated the dielectric cell to hold the powder sample such that one can introduce the sample in the cell conveniently by raising up the plunger without taking the cell outside and we need not go every time to release and tighten the screws. Due to this arrangement, equal pressure applied by the plunger on powder column in the cell. In addition to this, jacket is provided to the dielectric cell for giving circulation of water at required temperature. It is worth to point out here that determination of ($\lambda_d$) from this arrangement is more accurate than the method used by Bansal et al. [1] and Bhatnagar et al.[2] and we can measure the height of the powder column in the cell accurately and conveniently.

To determine the dielectric constant ($\in'$) and loss factor ($\in''$) of Pearl millet powder at microwave frequencies, Smyth and Heston relations [11] were used.

$$\in' = \left(\frac{\lambda_0}{\lambda_c}\right)^2 + \left(\frac{\lambda_0}{\lambda_d}\right)^2 \quad \ldots\ldots\ldots\ldots\ldots (1)$$

$$\in'' = 2\left(\frac{\lambda_0}{\lambda_d}\right)^2 \cdot \left(\frac{\alpha_d}{\beta_d}\right) \quad \ldots\ldots\ldots\ldots (2)$$

The conductivity ($\sigma_p$) and relaxation time ($\tau_p$) were obtained by using the following relations.

$$\sigma_p = \omega\varepsilon_0\varepsilon'' \quad \ldots\ldots\ldots (3)$$

$$\tau_p = \frac{\varepsilon''}{\omega\varepsilon'} \quad \ldots\ldots\ldots (4)$$

Where,
ω = 9.85 GHz (angular frequency of measurements)
$\in_o$ = is permittivity of free space.

The dielectric constant and loss factor for bulk materials can be found with the values from powder form the values obtained by using relations given by many workers [3, 4, 7 and 12].

## RESULTS AND DISCUSSION

The values of permittivity ($\in'_p$) and loss factor ($\in''_p$) along with the values of relative packing fraction ($\delta_r$) of Pearl millets are listed in table 1. The values of ($\in'_p$) and ($\in''_p$) obtained experimentally for different grain sizes and temperatures showed that there is systematic increase in dielectric constant ($\in'_p$) and loss factor ($\in''_p$) with increasing values of relative packing fraction ($\delta_r$) and decrease in ($\in'_p$) and ($\in''_p$) with increasing temperature. As packing fractions and temperature increases the moisture percentage decrease linearly. This is expected because with higher values of relative packing fraction ($\delta_r$) the inter particle hindrance offered to the dipolar motion of material in an electromagnetic field at microwave frequencies for a compact medium is much higher than for a material constituting less bounded particles[14]. Such observations have already been made by other workers [2, 4 and 12] for higher values of packing fractions.

On examination of values of relaxation time ($\tau_p$), conductivity ($\sigma_p$) along with values of relative packing fraction ($\delta_r$) for different temperatures indicates that there is a systematic increase in ($\sigma_p$) and ($\tau_p$) with the increasing values of packing fractions (δr) and decrease in ($\sigma_p$) and ($\tau_p$), values with the increase of temperature. Such behavior is expected because, when polar molecules are very large, then under the influence of electromagnetic field of high frequency, the rotary motion of the polar molecules of a system is not sufficiently rapid to attain equilibrium with the field. The polarization then acquires a component out of phase with the field and displacement current acquires a conductance component in phase with the field, resulting in thermal dissipation of energy. Thus, the dielectric loss is proportional to the a. c. conductivity. The increase in relaxation time ($\tau_p$), with increasing value of packing fraction is due to increasing hindrance to the process of polarization. The increase in conductivity suggests that at higher compaction, no micro cracks develop in the sample due to high mechanical pressure. From graph it is observe that as packing density increases linearly the values of dielectric constant, dielectric loss and conductivity increases. There is a systematic decrease of dielectric constant, dielectric loss and conductivity as temperature increases.

The decrease in relaxation time ($\tau_p$), with increasing the values of temperature may be due to the increase in effective length of dipole. Again increase in temperature causes an increase in energy loss due to the large number of collisions and thereby decreasing the relaxation time. Table 2 indicates the measured and computed values of dielectric parameters for bulk from powder measurements. The results reported $\delta_s$ = 1 are those measured on the finest crushed powder sample packed very closely in a sample holding dielectric cell at 98 N –force, to obtain minimum voids between the particles. The specimen having minimum particle size is defined as the finest that is about 70 or less micrometer in this case. We assumed this system as solid bulk for getting correlation between powder and solid bulk. Other results correspond to different values for δr < 1. To obtain transformation to 100% dense bulk, the correlation formulae of Landau-Lifshitz-Looyenga and Bottcher were used [3, 7, 8]. The bulk values obtained for ($\in'_p$) and ($\in''_p$) were very much closer to the measured values of ($\in'_s$) and ($\in'_s$) at δr = 1. This strongly supports the assumptions of Landau et al. [7] and Bottcher [3] of choosing the finest crushed closely packed powder sample as a solid bulk. Some author [2, 4, 12] found that there is a slight disparity between calculated values and experimental values of ($\in''_s$). This disparity in their results may be due to inaccurate measurement of dielectric wavelength ($\lambda_d$).

Table 1. Dielectric constant (Є'), dielectric loss (Є''), relaxation time ($\tau$p), conductivity (σp) and moisture percentage of Pearl Millet at different temperature and packing fraction (δr).

| Temp 0ºc | Packing Fraction (δr) | Є' | Є'' | tanδ | $\tau$p (p.s.) | Σp ($10^{-2}$) | Moisture (%) |
|---|---|---|---|---|---|---|---|
| 20 | 0.8971 | 3.141 | 0.463 | 0.147 | 2.38 | 25.32 | 0.875 |
| | 0.9663 | 3.195 | 0.560 | 0.160 | 2.58 | 27.88 | 0.751 |
| | 1.00 | 3.248 | 0.569 | 0.175 | 2.83 | 31.13 | 0.575 |
| 35 | 0.8971 | 3.086 | 0.437 | 0.141 | 2.29 | 23.91 | 0.743 |
| | 0.9663 | 3.120 | 0.462 | 0.148 | 2.40 | 25.28 | 0.632 |
| | 1.00 | 3.161 | 0.540 | 0.168 | 2.72 | 29.51 | 0.511 |
| 50 | 0.8971 | 3.054 | 0.378 | 0124 | 2.01 | 20.70 | 0.480 |
| | 0.9663 | 3.100 | 0.419 | 0.135 | 2.18 | 22.92 | 0.353 |
| | 1.00 | 3.125 | 0.462 | 0.148 | 2.39 | 25.30 | 0.236 |

Table 2. Measured and calculated values of dielectric constant (Є'), and dielectric loss (Є") for bulk from powder of Pearl Millet at different temperatures and packing fraction (δr)

| Temp 0ºc | Relative Packing Fraction (δr) | Є' For solid bulk | | | Є"For solid bulk | | |
|---|---|---|---|---|---|---|---|
| | | Measured | Calculated From Bottcher's formula | Calculated From Landu, et al formula | Measured | Calculated From Bottcher's formula | Calculated From Landu, et al formula |
| 20 | 0.8971 | ----- | 3.470 | 3.407 | ----- | 0.551 | 0.541 |
| | 0.9663 | ---- | 3.295 | 3.231 | ------ | 0.538 | 0.535 |
| | 1.00 | 3.248 | 3.248 | 3.170 | 0.568 | 0.569 | 0.569 |
| 35 | 0.8971 | ---- | 3.406 | 3.349 | ----- | 0.520 | 0.511 |
| | 0.9663 | ---- | 3.217 | 3.163 | ------ | 0.488 | 0.485 |
| | 1.00 | 3.161 | 3.161 | 3.090 | 0.540 | 0.539 | 0.539 |
| 50 | 0.8971 | ----- | 3.369 | 3.330 | ----- | 0.450 | 0.442 |
| | 0.9663 | ----- | 3.195 | 3.151 | ----- | 0.442 | 0.440 |
| | 1.00 | 3.125 | 3.125 | 3.070 | 0.462 | 0.462 | 0.462 |

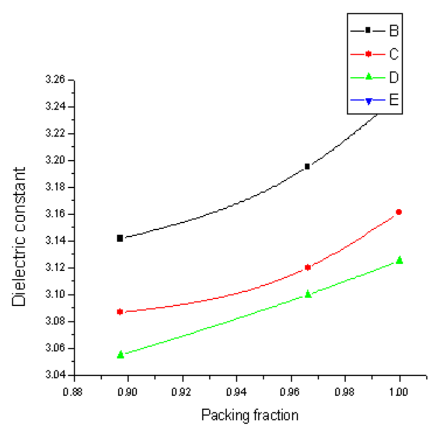


Fig.1: Packing fraction Vs Dielectric constant

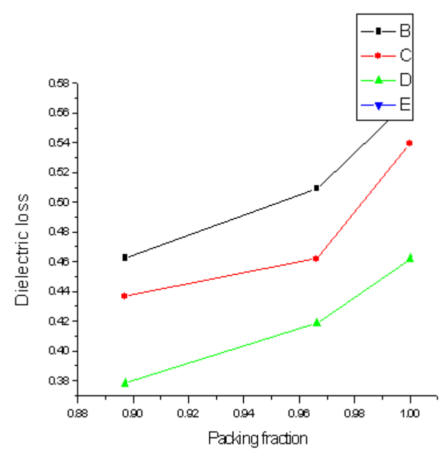


Fig. 2: Packing fraction Vs Dielectric loss

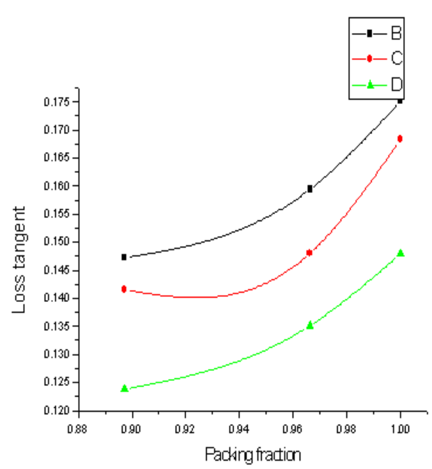


Fig 3. Packing fraction Vs Loss tangent

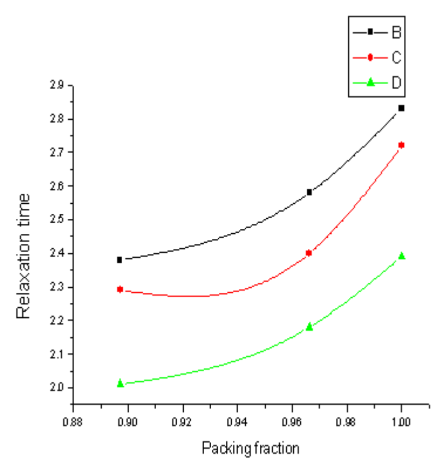


Fig 4. Packing fraction Vs Relaxation time

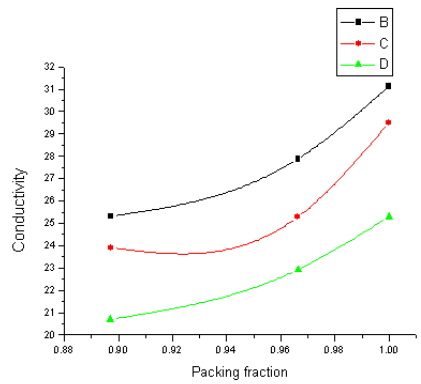


Fig 5. Packing fraction Vs Conductivity

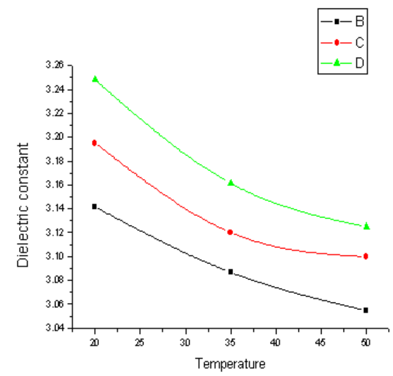


Fig 6.Temperature Vs Dielectric constant

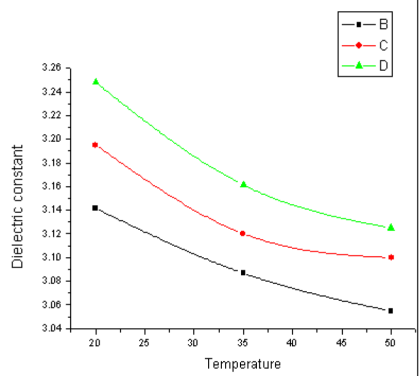


Fig 7.Temperature Vs Dielectric constant

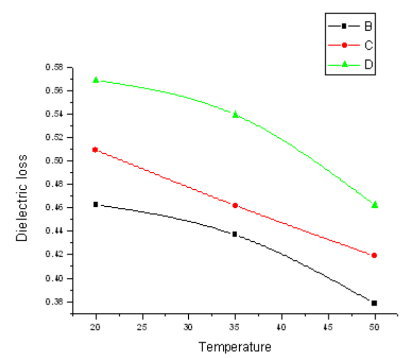


Fig 8.Temperature Vs Dielectric loss

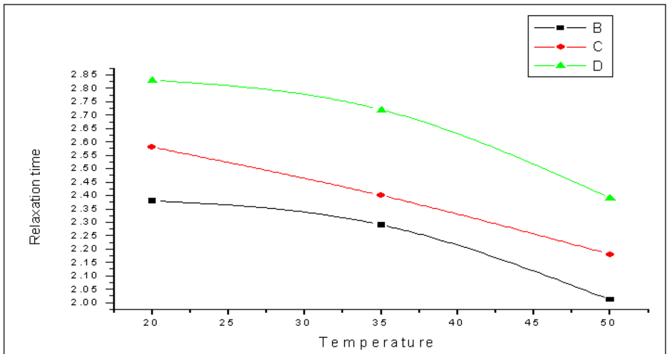


Fig 9.Temperature Vs Relaxation time

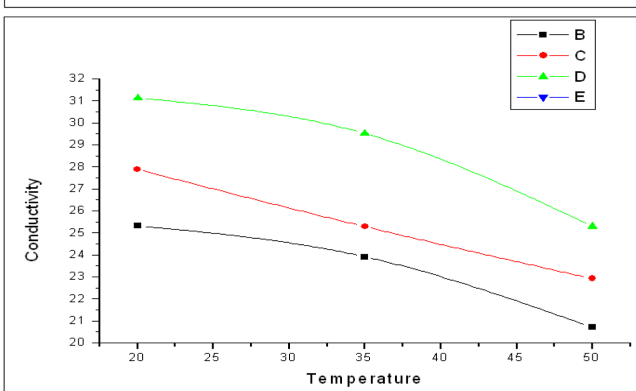


Fig 10. Temperature Vs Conductivity

## CONCLUSIONS

There is a fair agreement between the values obtained experimentally and theoretically. This shows large cohesion in the particles of pulverized Pearl millet under investigation serve as continues medium. The correlation formula of Landau-Lifshitz-Looyenga and Bottcher between powder and solid bulk works well.

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